1.a.i.	A change in direction of the motion	(not Mercury, Venus)	1
	of planets as seen from Earth		1
ii.	any two from the following:		
	all solar objects orbit the Earth	(disallow: elliptical)	
	planets should not change direction		
			2 max.
b.	Sun at centre		1
	Circular orbits		1
c.	Planets orbit Sun with different speeds.		1
	Overtaking of planets		1
d.	any 2 from the following;		
	inferior predictions to Ptolemaic model		
	stellar parallax not observed		
	Earth not felt to be moving		
	No 'wind'		
	direction of free falling objects would not be vertical		
			2 max.
2.a.	Nuclear fusion or p – p reactions		1
	Mass to energy conversion/ $E = mc^2$		1
	Hydrogen converted to helium		1
b.i.	x-axis: temperature/ colour index/ spectral class		1
	correct direction: T to left; B ← R; O - M to right		1
	y-axis: absolute magnitude/luminosity		1
	correct direction; M down; L up		1
b.ii.	On main sequence, in lower half		1
c.i.	expansion		1
	decrease in temperature/ redder in colour		1
c.ii.	Hydrogen depletion in core		1
	Helium /carbon burning		1
d.	A: burns fuel quickly so very short lived		1
	B: intensity of radiation is low		1

3.a   720nm $\pm$ 5 nm   1

  b.i.   wavelength of Ly α increased/ red-shifted   1
        quasar receding   1

  c. $z = 720/121.6 - 1 = 4.92$ ECF   1

  d.i.   from graph; $v/c = 0.94 \pm 0.005$ ECF   1
        $v = 0.94 \times 3 \times 10^8 = 2.82 \times 10^8$ m s^{-1} ECF   1

  d.ii $H_0 = (70 \times 1000)/(10^6 \times 3.1 \times 10^{16}) = 2.33 \times 10^{-18}$ s^{-1} 1

        $r = v/H_0 = 0.94 \times 3 \times 10^8 / 2.33 \times 10^{18}$ m $= 1.21 \times 10^{26}$ ECF d.i and d.ii   1

        distance $= 1.21 \times 10^{26} / (3 \times 10^8 \times 365 \times 24 \times 60 \times 60)$
        distance $= 1.3 \times 10^{10}$ ly   1

        special case: 1 mark for $r = v/H_0$ if no other marks scored.

  d.iii.   the value of H_0 has not changed   1

  e.   Terrestrial is change of wavelength/frequency due to relative motion   1
       blue shift possible for approaching sources   1
       Cosmological red shift is change of wavelength due to expansion of space 1

4.a   Any three from:
       final stage of stellar evolution
       low mass stars / correct reference to Chandrasekhar limit
       High density
       Small/hot /faint
       Fermi pressure prevents further collapse   3 max

  b.i.   any 5 points plotted correctly   1
        sixth point correct   1

  b.ii.   best-fit straight line drawn
         (2 points on each side of line; length minimum of half the grid <u>horizontally</u>) 1
         n = gradient of graph   1
         $n = 4 \pm 0.2$ ECF from line drawn   1

5.a.   any 6 points from:
1. initial singularity
2. high temperature
3. emergence of weak/strong/electrostatic force
4. matter-antimatter imbalance
4. pair-production from radiation/matter-radiation interchange
5. formation of protons/hydrogen <u>nuclei</u>/quarks/leptons/electrons/neutrinos
6. early stage helium nuclei formed
7. universe cools
8. recombination of electrons and protons

                                               6 max: 6

b.   open when $\Omega < 1 \, / \, \rho < \rho_0$ 1
        universe expands for all time   1

        flat when $\Omega = 1 \, / \, \rho = \rho_0$ 1
        universe <u>just</u> expands for all time   (owtte)   1
        special case if M1 mark not scored:

        closed when $\Omega > 1 \, / \, \rho > \rho_0$ 1
        expansion eventually halts/ universe collapses/big crunch   1

c.   dark matter/hydrogen gas /helium gas   1
        affects motion of galaxies/   1

6.a.   accept any suitable arrangement.
1. accelerating spacecraft
2. with front and rear light clocks
3. pulse from front clock arrives before pulse from rear clock
4. rear clock appears to run slower than front clock to observer in craft
5. gravity equivalent to acceleration
6. clocks must run slower in gravitational field

                                                Any 5

b.i. $E = 14.4 \times 10^3 \times 1.6 \times 10^{-19} \text{ J } (= 2.3 \times 10^{-15} \text{ J })$ 1
        $E = hf$ 1
        $f = 2.3 \times 10^{-15} / 6.64 \times 10^{-34} = 3.5 \times 10^{18} \text{ Hz}$ 1

b.ii $\Delta f \, / \, f = - (9.81 \times 22 / 9 \times 10^{16}) = - 2.4 \times 10^{-15}$ 1
        $\Delta f = 2.4 \times 10^{-15} \times 3.5 \times 10^{18} = 8.4 \text{ kHz}$ 1
        (using $f = 4.0 \times 10^{18}$ gives $\Delta f = 9.6 \text{kHz}$)

c.   GPS satellites/ light from object falling into black hole/
        light from large/dense star   /synchronising atomic clocks in aircraft/satellites   1

7 (a) (i)	Mass	$= 0.15 \times 5 \times 60$	1
		$= 45$ kg	1
(ii)	Energy required	$= 45 \times 4200 \times (38 - 8)$ Must have temperature difference	1
		$= 5.67 \times 10^6$ J	1
(b) (i)	Work done	$=$ Force $\times$ distance turned (Allow F.d)	1
		$= 80 \times 2\pi \times 0.2$	1
		$= 100$ J	
(ii)	Power produced	$=$ Energy per rev. $\times$ Number of rev. per second	
		$= 100 \times 1.3$	
		$= 130$ W	1
(iii)	Total number of revolutions	$= 5.67 \times 10^6 / 100$	
		$= 56700$	1
(iv)	Time for pedalling	$= 56700 / 1.3$	
		$= 43615$ secs	1
		$= 12.1$ hours	1
c (i)	Total resistance in heater circuit	$= EMF / \text{current}$	1
	Must see some evidence of equation used and physics of problem other than $V = IR$ eg $R_{total} = R_1 + R_2$		
		$= 24 / 5$	
		$= 4.8 \; \Omega$	1
	Resistance of element	$= 4.8 - 1.2$	1
		$= 3.6 \; \Omega$	
(ii)	Length or wire	$= RA / \rho$	1
		$= 3.6 \times 0.32 \times 10^{-6} / 1.5 \times 10^{-7}$	1
		$= 7.68$ m	1
d	Discussion on energy losses	Work done against friction in bearings etc	1
		Power loss from resistance of generator and connecting wires	1
		Heat radiated from tank	1

In one second student outputs 130 J of which only 120 J to generator
and only 90J to tank
Thus pedalling time will be longer by factor 130 / 90 giving a new time of 17.5 hours. 2

(Any explained energy loss plus extra time calculations scores up to 2 marks)
(Any correct calculation of extra time scores 1 mark)
                                            Maximum 4 marks for question

Up to 3 marks for intelligent discussion (but ignore sound)
Up to 2 marks for calculation   **Max 4**